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CHEMICAL RESEARCH AND NATIONAL WELFARE

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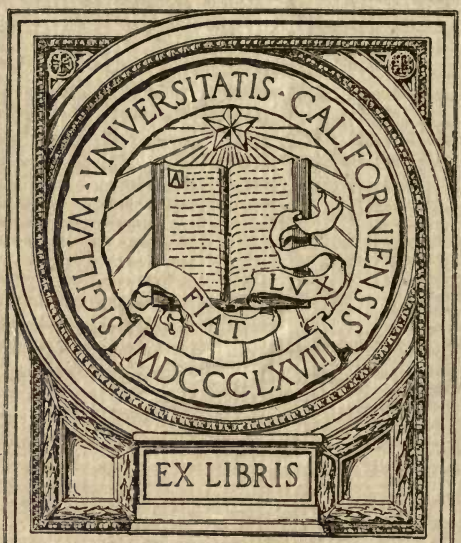

CHEMICAL RESEARCH

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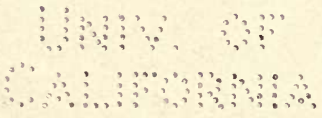
IN ITS

BEARINGS ON NATIONAL WELFARE

[INCORPORATING, BY PERMISSION OF PUBLISHERS OF "NATURE," A LECTURE DELIVERED BY PROFESSOR EMIL FISCHER IN BERLIN, JANUARY 11, 1911]



LONDON
SOCIETY FOR PROMOTING CHRISTIAN KNOWLEDGE
NORTHUMBERLAND AVENUE, W.C.; 43, QUEEN VICTORIA STREET, E.C.
BRIGHTON: 129, NORTH STREET
NEW YORK: E. S. GORHAM
1912

QD31
F5

PUBLISHED UNDER THE DIRECTION OF THE
GENERAL LITERATURE COMMITTEE

[illegible]

UNIV. OF CALIFORNIA

CHEMICAL RESEARCH

INTRODUCTORY

DURING the past century the scope of technical industry has developed to an extent even greater than that attained during the many previous centuries of the Christian era, and this sudden development has been coincident with the rapid progress of experimental science in the hands of the last four generations. It is not within our present purpose to enter in detail into the reasons for this phenomenal growth ; but we may well consider the close relation between the advance of experimental knowledge and the development of chemical manufactures.

From the earliest records of man we learn that the most primitive industries were based upon the imitation of natural processes ; but with the advent of the more cultured ancient civilisations, such as those of the earliest Egyptians and Assyrians, man, in his gropings, had stumbled upon processes, often to us astonishingly subtle, by means of which he could convert to his use the raw materials of nature. Examples of these are the

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reduction of ores and the refining of metals, and the preparation of glass and enamels. Of systematic or intelligent investigation from a theoretical standpoint there was practically nothing; all processes were based upon the accidental discoveries of random experimentation. Nevertheless, such progress in material welfare as was made was entirely due to trial and observation.

But as soon as men began to attempt to co-ordinate their observations, and thus lay the first stones in the beautifully symmetrical and interdependent mosaic of science, advance became rapid. From the orderly arrangement of known facts it became possible to predict and establish further facts, each new observation leading to others. Thus it was not long before industries were established which involved the known processes of science, and to the furtherance and technical improvement of these processes the methods of science were applied. It is therefore evident that the welfare of industry is directly contingent on the progress of science, however purposeless and theoretical the line of advance might at first sight appear.

Of all nations, Germany has been the one to appreciate this fact the most keenly. The German mind, although by no means strikingly original, is rapid to perceive, ready to adapt, and methodical in the development of lines initiated by its neighbours. From the outset science has been carefully

fostered in that country, with the result that in no other have technical industries attained such importance. No nation has been able to compete against the scientifically managed manufactures of Germany, many of the most important of which were originally instituted in England, France, or the United States. No other country can boast of a single business combination, comprising three firms (the chemical factories of Elberfeld, Ludwigshafen, and Treptow), which employs over seven hundred qualified chemists.

And yet, in spite of the unique facilities already afforded by Germany for the prosecution of pure science, further aid has been demanded and granted. The German government has for many years endowed the universities and technical schools—which indeed are under the direct control of the State—with annual sums vastly greater than those applied to similar purposes in England. In addition to this indirect method of furthering the progress of science, a Society for the Promotion of Science has recently been constituted.

The idea of founding such a society is by no means a new one; for years the most prominent men of science in German university circles had been endeavouring to set on foot such a scheme. They were unable, however, to reach the ear of the wealthy members of the community whose aid was indispensable to the project; and not until the German Emperor, that most eminent of all dilettanti,

embraced the scheme with his customary impetuosity, was the attention of the philanthropic rich directed towards this need of science.

The Kaiser-Wilhelm Society, taking the name of its protector and patron, defines in its first statute its primary object: "To promote the sciences, especially by the foundation and support of scientific institutes of research." The income of the society, subscribed by private individuals or by firms, will be devoted to the establishment of institutes of research in which distinguished investigators in the various branches of science will be afforded facilities and means for the prosecution of their chosen problems. They may also, if they so desire, call in the collaboration of younger men, students who are intending to graduate in one of the State universities. By this means much of the drudgery involved in all research may be transferred from the shoulders of the master-thinker to those of his disciples, who thereby acquire not only knowledge of the methods of experimentation, but, what is even more important, the spirit underlying all scientific investigation.

"Such[1] a position was held, as member of the Berlin Academy, by Prof. van't Hoff, whose recent removal by death the whole scientific world deplores. He had a free hand, was not obliged to give any formal lectures or to take part in the

[1] Sir William Ramsay, *Nature*, March 16, 1911.

active management of the University, but was allowed, with the help of students, to work out his own problems in his own way, and his work on the Stassfurth salts has been of great technical value. His words to the writer were, many years ago, that he thought it right to help his adopted country to solve its commercial problems, and that he had attempted to do so. But it must be understood that no such expectation is necessarily entertained of the incumbents of chairs at the proposed institutes; the progress of *science*, not necessarily of its industrial application, is contemplated. Our neighbours have learned the lesson that science, like virtue, brings its own reward.

"It is wonderful how deeply the spirit of trust in science has penetrated the whole German nation. When Prof. Ostwald, many years ago, appealed to the Saxon Government for money to build his physico-chemical laboratory, the Socialists in the Saxon Parliament voted for the grant to a man, believing that greater expenditure on pure science would contribute to greater industrial opportunities. This spirit, which permeates the German people, from the Emperor on his throne to the representative of the peasants, causes admiration; would that it could inspire imitation!

"One is led to speculate on the cause of this. Why is it that the people of Germany have such sympathy for scientific endeavour? The reasons are many.

"First, and above all, is the discipline that the German people have undergone by their military training; more are thus prepared for practical life in a measure which cannot be otherwise attained. It has its disadvantages; on the whole, the people are not so self-reliant, but they become more trustworthy machines. Second, there is a deeper understanding of scientific achievements and their bearing on industry. This manifests itself in many ways; the German Government is not above asking for, and acting on, scientific advice. The social position of the savants, scientific and literary, is therefore assured, and the incomes of the higher posts compare favourably with those earned by professional men and manufacturers. This higher social standing secures attention to those who tender advice. Third, there is a constant exchange between academic and industrial posts; many men leave chairs to become managers of factories; many men enter the teaching and investigation profession from factories. Chemical and physical factories, too, there form a training school for the younger scientific experts; where many are employed, the more advanced communicate their knowledge and the results of their experience to the junior members of the scientific staff; in fact, they have apprenticeship at its best. Here, in prosperous times, the manufacturer thinks that he has no need of scientific assistance; in times of bad trade he believes that he cannot afford it. And,

lastly, the process of training the people has gone on in Germany for nearly a hundred years. Rewards have been given, not to successful examinees, and not in the form of scholarships ; but have been earned in the battle of life, for which ample preparation had been given.

" This spirit of trust in science has permeated to the highest in the land ; that it has been fertile in practical results is amply proved by the inception of the Kaiser-Wilhelm Society for the Furtherance of Science."

Thus, " Germany, and at its head, the Emperor, have again shown the world their gratitude for the achievements of science ; if desired, the word 'gratitude' may be interpreted in the sense of 'favours to come.' . . . It is instructive to note the difference between their methods and ours. Both countries possess what is called 'technical education' ; but while we have founded schools in considerable number, destined to capture the workmen (who seldom attend) and the prospective foremen, they have aimed at the education of the manufacturers and the works managers. Instead of numerous institutions giving elementary science instruction, they have a few imparting the most advanced. Instead of a system of small scholarships, intended to bribe the clever children of the lower middle class, they leave it to the parents to find out that their children, suitably trained, are equipped for their life work, and will, if they are

diligent, be certain of reasonable incomes and respectable positions."

An idea of the commercial supremacy of Germany, due to its scientific activity, may be formed from the following figures, taken from the last available census (1907). In that year the chemical industries of Germany produced goods amounting in value to over £750,000,000, placing this industry inferior only to those of metals and textile goods—both of them industries largely owing their present prosperity to science. Chemical manufacture in Germany gives employment to no less than two hundred thousand persons; an exceptionally large proportion of whom, as compared with other industries, earn the higher wages of skilled labour. It is interesting to note that no less than one-sixth of the individuals employed in chemical industry are females.

The story of the rise of chemical industry in Germany to its present paramount position is an instructive one; clearly showing that—although the Germans, as already remarked, may not be gifted with that inventiveness and power of origination which is apparently a prerogative of those peoples who stand foremost in the struggle for individual liberty—they have been able to win the foremost place in this branch of international commercial competition through the attention which they have devoted to scientific research and the systematic application of its results.

An instructive example of the methods by which they have fostered their industries is to be found in the manufacture of alkalies. Germany is, as is well known, exceptionally rich in deposits of mineral salts—that at Stassfurth being the most remarkable —and in order to utilise the large quantities of sodium chloride available, the Leblanc process, devised in France and first worked in England, was adopted for the production of soda. Prior to 1840, Britain had supplied the bulk of the alkali imported into Germany, but before long Germany was in a position to export this commodity herself. In the Leblanc process, hydrochloric acid is formed as a by-product, and as this cannot advantageously be transported for any considerable distance, bleaching powder and other products of chlorine resulted, and for these a commercial application had to be found in order to enable the process to be carried on economically.

The balance of consumption thus established was, however, rudely disturbed by the perfection, in Belgium in 1861, of Solvay's ammonio-soda process, by which sodium carbonate could be manufactured at far less cost. The Leblanc process therefore rapidly lost its footing throughout Europe, and would soon have been entirely superseded, had not systematic attempts, effected by the constant endeavours of research, been made to find an advantageous application for its by-products. Such a field was found in the manufacture of coal-

tar colours, established in England by Perkin in 1856; and to such an extent was this industry developed by the Germans, that by the year 1897 Germany was annually exporting coal-tar colours to a value of £4,500,000, a figure which was doubled ten years thereafter.

The raw materials for these colours are obtainable equally readily in England and in Germany. We thus see the result of the carefully planned interdependence, rendered possible by chemical research, of the decaying with the rising industries. It would have been too much to expect England to be able to retain the supply of practically the whole world with alkalies, as the resources of the British saline deposits are far inferior to those of Germany. But it was needless—and a humiliation to British enterprise and perspicacity—that, for the lack of ample chemical research, the supremacy in the coal-tar colour manufacture should have been lost.

At the inauguration of the Kaiser-Wilhelm Society in Berlin a lecture was delivered before the Emperor and a gathering of the most distinguished men of science in Germany by Prof. Emil Fischer, the world-renowned investigator in organic chemistry. In this address Prof. Fischer traced the relations between scientific chemistry and chemical industry in Germany, pointing the moral that by affording facilities for the prosecution of pure scientific research, technical

industry — and with it the welfare of mankind generally—gains in a corresponding degree; the bread cast upon the waters of science being returned after many days in benefits to humanity. Extensive quotation from this lecture will be made in the subsequent pages.

The foundation of this first national Institute for the Promotion of Science provides us with the occasion for making the present plea on behalf of Chemical Research. It is earnestly to be hoped that the example given by this establishment may soon lead to the provision of like opportunities for conducting scientific investigations in Britain and other countries. The appeal for the encouragement of that research which has led to such brilliant results in Germany is not new to English ears. Prof. Huxley, in his address on Technical Education, delivered as long ago as 1877, remarked with characteristic vigour: "I would make accessible the highest and most complete training the country could afford. Whatever that might cost, depend upon it the investment would be a good one. I weigh my words when I say that if the nation could purchase a potential Watt, or Davy, or Faraday, at the cost of a hundred thousand pounds down, he would be dirt-cheap at the money. It is a mere commonplace and everyday piece of knowledge, that what these three men did has produced untold millions of wealth, in the narrowest economical sense of the

word." What might not have been accomplished, for the interests of Great Britain and the benefit of humanity at large, if these words had led, a full generation ago, to the establishment of a British Institute for the Promotion of Research; a predecessor of that which has now arisen in Berlin.

MODERN ACHIEVEMENTS

PROFESSOR FISCHER, in the opening remarks of his lecture to the Kaiser-Wilhelm Society, pointed out that in many branches of science, and in physics and chemistry in particular, many of the fundamental laws upon which these sciences were built up have, in the fierce light of modern research, proved untenable or insufficient: "At the present time," he says, "more than at any other period, we are inclined critically to examine the fundamental principles of all branches of knowledge, and, when necessary, to introduce far-reaching alterations in our original conclusions. This state of mind applies particularly to the natural sciences. During the last decades our actual knowledge has been extended to an extraordinary degree owing to new methods of research, and in view of the most recent observations the older theories have proved in many cases to be far too narrow. Even the fundamental principles of our knowledge appear, to a certain extent, to demand revision.

"Thus the progress in physical science forces us to adopt views which are incompatible with the older principles of mechanics, in spite of the fact that these were regarded as unassailable by thinkers

such as Hermann von Helmholtz, Heinrich Hertz, and Lord Kelvin.

"The same state of affairs obtains to even a greater degree in the biological sciences. In comparative anatomy, animal and vegetable physiology, theory of evolution, microbiology, and almost all branches of medical science, the rapid advance of experimental knowledge is accompanied by an equally rapid change in established theories. Even the semi-historical sciences, such as geology, palaeontology, anthropology, and the venerable science of astronomy, are taking active part in the general progress."

It must not be imagined, however, that these original principles, although ultimately rejected, were misleading or of no value to the science. By means of such theories alone are we able to advance our knowledge to the point at which they may be cast aside ; without some such guiding principles we can only grope in the dark. As it is with these far-reaching laws, so it is with the lesser theories, which may be in vogue for only a few seasons. These, too, in inviting research which may tend either to their confirmation or their refutation, lead the investigator along paths by the side of which he is able to observe new facts.

Of recent years physicists have been forced to the conclusion that mass, that function of matter which has hitherto been regarded as absolutely unalterable, is capable of appreciable variations under different

conditions. According to the now generally accepted "Principle of Relativity," a constant force does not, as has hitherto been assumed, produce a constant acceleration in a moving body; as the velocity of the body increases, the acceleration diminishes. In other words, in order to produce in a moving body a constant acceleration, a continually increasing force must be applied. In addition to this, the physical conception of time has been modified in the same way with respect to bodies in motion.

"We stand in the same position with regard to the elements in chemistry. Owing to the discovery of radium and similar bodies, we have been forced to the conclusion that chemical elements are not unalterable and that their atoms are hence not indivisible.

"Thus in these times of general scientific activity is founded the Kaiser-Wilhelm Society for the Promotion of the Sciences, the primary object of which is the erection and maintenance of institutes of research.

"It need scarcely be said that we scientific investigators welcome this new and highly specialised creation with intense satisfaction.

"No one will be able to assert that experimental research in Germany has been neglected; exactly the opposite conclusion must be drawn on contemplating the history of science during the nineteenth century. This displays a long series of brilliant

scientific discoveries. The industries closely connected with science, such as the chemical and electrotechnical industries, fine mechanical engineering, metallurgy, industries connected with fermentation, and last, but not least, agriculture, have also undergone in our hands a development envied on all sides.

"Should a criterion of the results of experimental research be desired, this may perhaps be found in the distribution of the Nobel prizes, which are awarded by absolutely independent corporations in Sweden. Only a month ago (1910) the Nobel prize for chemistry came for the sixth time to Germany; this constitutes sixty per cent. of all the Nobel prizes hitherto awarded for chemistry. During the same period of time two-and-a-half prizes were awarded to Germans for physics and three-and-a-half for medicine. Dr. Alfred Nobel, unfortunately, did not provide for the remaining natural sciences.

"The majority of the investigations distinguished by the award of these prizes, however, belong to the nineteenth century. Since that time matters are to some extent altered. It is well known that the greater number of scientific investigators are teachers at universities or polytechnics. During the last ten years a scheme of practical education of the masses has developed which affords to all students the possibility of acquiring a thorough training in experimental science, and which pro-

vides our industries with an army of scientifically educated workers. But this very education of the masses tends mentally to exhaust the teacher to a great extent, certainly to a higher degree than is desirable or indeed compatible with the creative power of the investigator.

"There prevails in modern educational laboratories a condition of overstrained activity comparable with that existing in all but the smallest factories and commercial offices, and in the harassing cares of the day the teacher too readily loses that peace of mind and broad view of scientific matters necessary for tackling the larger problems of research. This danger has been most keenly appreciated by teachers of chemistry. It is therefore no mere accident that in our circles of recent years the cry for new laboratories should be at its loudest; an appeal for laboratories which should permit of research in absolute tranquillity, unencumbered by the duties of teaching.

"But all our efforts were fruitless, in spite of the active support of an industry ready to make any sacrifice, and we were about to abandon, with reluctance and with sadness, our cherished plan, when the action of your Majesty in directing the attention of all munificent ladies and gentlemen in Germany to the need of supporting scientific research came to us like a heaven-sent aid.

"In place of the one State-supported chemical institute which we had planned, chemists may now

anticipate the immediate possession of two such institutes in which gifted men may conduct their original researches with ample means in freedom from any other duties. It is anticipated that the younger generation of chemists will thereby derive especial benefit. By the younger generation I mean in particular those men who are at present acting as assistants or lecturers in University laboratories, and who can carry on research in addition to the servile labour of teaching only by possession of an extraordinary capacity for work.

"That which applies to chemistry may, *mutatis mutandis*, be applied to the other sciences, and is especially applicable to new branches of knowledge, for the prosecution of which the laborious organisation of educational laboratories leaves no possibility. The handicap under which we work, in comparison with other nations, in particular the United States of America, in which similar institutes have recently been founded, can thus be removed. If the hopes which we all place in the new institutes are fulfilled, Germany will in the future not lack recipients of the Nobel prizes, and we may then hope to maintain the honourable position which we hitherto have held in the domain of science.

"That this is not only a matter of sentiment and honour, but of palpable advantage in material respects, is at once evident from the close relation between modern scientific progress and national well-being. I am not here to demonstrate this

relation by means of statistics or political-economical considerations. On the contrary, I would invite your attention to a cursory review of my own science. I shall thus, in considering the most recent achievements in this field, be able to point out to you the diversity of the problems and their fertility with regard to the most varying branches of technical industry."

The general properties of radium are now so well known to the public that a detailed description is unnecessary. Its discovery in 1902 by Madame Curie in Paris is one of the most remarkable achievements of chemical research, and, as has been pointed out, has revolutionised the fundamental theories upon which science is based.

The study of radio-activity itself had preceded the isolation of radium salts. Its investigation originated about the year 1880, when Sir William Crookes began his systematic observation of the phenomena of electric discharge through a high vacuum. He explained the fluorescence of the glass constituting the vacuum tubes which bear his name as being due to the bombardment of the walls of the vessel by extremely minute particles, which were subsequently shown to be the products of the gas originally contained therein, and demonstrated that identical phenomena were produced, whatever the nature of the gas originally present. Sir J. J. Thomson has calculated that the mass of these particles is no greater than one seven-

hundredth of that of an atom of hydrogen, and that they travel with the inconceivable velocity of twenty thousand miles in a second, that is to say, with a velocity of about one ninth of that of light.

Now when the stream of these particles, or, as they are now termed, "electrons," is suddenly obstructed, as it is by the glass walls of the Crookes tube, the electrons are deflected and the glass vibrates in sympathy with the high frequency of the impacts, giving rise to fluorescent light. At the same time the sudden interruption of the flight of the particles sets up a stream of non-periodic pulsations in the ether, these taking the form of rays, termed "cathode rays" from the fact that they proceed in straight lines from the cathode, or negative pole.

A further contribution to our knowledge of this class of phenomena was Röntgen's discovery that cathode rays were able to pass through such substances as wood or thin aluminium foil. Röntgen came upon this fact by the accidental fogging of a number of photographic plates enclosed in dark slides which were exposed to the effect of a Crookes tube. Though these rays are thus seen to be endowed with actinic power, and to be capable of passing through substances opaque to ordinary light, they are invisible to the human eye. It was, however, soon discovered that, in addition to glass, certain other chemical compounds, such as zinc sulphide or barium platinocyanide, possessed the property of emitting a fluorescent light when placed

in the path of these rays. By this means direct X-ray examination of the living body has been rendered possible.

We cannot here enumerate the manifold humanitarian uses to which these cathode rays have been adapted, but chief among these are their application to diagnostic surgery and to the cure of skin diseases such as lupus. Nevertheless, while they are instrumental in effecting marvellous cures of such pathological conditions, prolonged exposure of healthy limbs to their influence unfortunately has the result of causing incurable ulcers which may lead to the total loss of the part affected. Thus some medical men who have made a specialty of this work have so injured their hands and arms as to necessitate the amputation of these members. It may here be noted that the γ-rays emitted by radium (see below) have recently been stated to cure the evil effects of Röntgen rays ; an interesting example of the subtle nature of the action of such radiations upon living cells.

In 1896 the French physicist Becquerel investigated the nature of a similar radio-active phenomenon. For some months he had been carrying in his waistcoat pocket a lump of an ore termed "pitch-blende," and had suffered from an ulcer of increasing virulence which appeared in the neighbourhood of the lump of pitch-blende shortly after he had exposed his body to its continued action. Coupling this with the fact that salts of uranium, of which pitch-blende is the chief ore, were known

to emit a faint light, he was led to an investigation of the nature of the phosphorescence of uranium salts. The conclusion that he reached was that the rays evolved by this mineral bear a marked similarity to the Röntgen rays.

The chief point of difference between the phosphorescence of uranium and that of other phosphorescent minerals, such as calcium sulphide, is that these latter substances glow in the dark only after exposure to sunlight, the intensity gradually diminishing, while the phosphorescence of radio-active bodies persists undiminished in the absence of light.

Becquerel found that the radio-activity of crude uranium, which was low, could be concentrated by mixing a solution of an uranium salt with barium chloride, and then adding sulphuric acid. The precipitate of insoluble barium sulphate was found to have carried down with it the source of the radio-activity, leaving behind an inactive solution of uranium. The inactive uranium, on standing for some months, was however found to regain its original activity. Crookes followed this up by isolating from uranium salts, by means of fractional crystallisation, a highly radio-active constituent which he termed " Uranium X."

But besides uranium, pitch-blende contains a variety of other elements. From the residues of this mineral, after the extraction of the uranium, Madame Curie, in collaboration with her husband, finally succeeded in isolating in a pure state the

chloride of the now famous metal radium. Some idea of the laborious nature of the task may be gathered from the fact that from one ton of pitch-blende she obtained no more than one-tenth of a gram (about one and one-half grains) of radium chloride. Subsequent work has shown that somewhat larger yields can be obtained by fractional crystallisation of the bromides.

Radium salts, in common with the salts of the other radio-active elements, such as uranium X (from uranium), polonium (from bismuth), actinium, thorium X, and mesothorium (from thorium), evolve rays which can be subdivided into three classes, designated α, β and γ, these being in the order of their penetrative powers. The β rays have been shown to be similar to the cathode rays of the Crookes tube. In addition to the emission of these rays, radium slowly breaks down into a gaseous element, at first termed "radium emanation," but after its isolation and examination by Dr. Whytlaw-Gray and Sir William Ramsay recognised as a chemical element and termed "Niton." These investigators have found that it forms a phosphorescent liquid at low temperatures under high pressure, exhibiting all the phenomena of a radio-active element. They have also been able to assign to it a position in the periodic table in the same group as the inert gases helium, neon, argon, krypton, and xenon.

We thus see that radium gradually disintegrates with formation of a second element, the rate at

which the radium breaks down being such that after a lapse of about thirteen centuries it will have dwindled to one-half its original amount. Furthermore, the emanation niton, being a radio-active element, itself breaks down spontaneously into helium, the half-life-period being in this case about three and three-quarter days. It is therefore evident that radio-active elements, by their very nature, break down into other elements of lower atomic weight.

Like the Röntgen rays, the rays evolved by radio-active bodies possess definite and powerful physiological action, and their value in medicine is daily becoming more widely appreciated. The great disadvantage of radium is, however, its intense activity. Just as the Röntgen rays give rise to malignant ulcers, so does radium, and in a far higher degree. It is therefore necessary for the operator to encase his external members in an armour of lead, a metal almost impermeable to the destructive β rays.

"As has already been remarked, our conception of the nature of chemical elements has to some extent altered owing to the discovery of radium. We are now acquainted with more than twenty-four such substances—the so-called radio-active elements—and we recognise that they disintegrate spontaneously, and that elementary transmutations are hence possible.

"Germany took at the outset only a small part

in the notable researches connected with the discovery of these elements, although the first stimulus leading to the discovery of radio-activity was given by the Röntgen rays. The reason for this is that Germany possesses none of the raw materials necessary for the production of radium, and that the majority of German investigators have not the means for the purchase of this costly element. This lack of means was especially keenly felt when radium first found profitable application in the field of medicine.

"We are therefore all the more delighted to record such an event as the recent discovery, due to Professor Otto Hahn of the chemical laboratory of the University of Berlin. He has for several years been investigating the disintegration products of thorium, which is employed in large quantities in the manufacture of incandescent mantles, and has in the course of his work discovered several radio-active elements, the most important of which he has designated mesothorium. He has, moreover, succeeded in devising a process for the isolation of this substance from the valueless waste products occurring in the manufacture of thorium. I am therefore able to show you a specimen of Hahn's preparation. This is the bromide of mesothorium, a white salt, which evolves the same highly penetrating rays as the corresponding salt of radium. A quantity of this substance, equivalent in radio-active power to 100 milligrams of pure radium

bromide, costs only one-third as much. Nevertheless, it is not cheap, since for this small quantity of material £550 was paid. Thanks to an endowment from Dr. von Bottinger, of Elberfeld, the Berlin Academy of Sciences will in a few months be in possession of 250 milligrams of this substance, and will be able to lend this amount to German investigators. It would be possible yearly to produce in Germany from the hitherto valueless residues after the extraction of the thorium, a quantity of this preparation of Dr. Hahn's equivalent to more than 10 grams of pure radium bromide. This is approximately equivalent to the world's stock of radium. By this discovery the radium famine hitherto prevalent in Germany may be said to be relieved."

It may here be pointed out that Dr. Hahn, though a German, made the first observations leading to the discovery of mesothorium in the chemical laboratory of University College, London, while working, under the guidance of Sir William Ramsay, upon some thorianite residues given to him by that brilliant investigator.

In the above excerpt Professor Fischer mentions the manufacture of thorium. Here we see the foundation and growth of a huge industry, based originally upon the most abstract and purely scientific research: the industry of incandescent mantles. In 1885 the German chemist von Welsbach, in the course of an investigation of the rare metals of the thorium group, found that the oxides

of these metals, and in particular that of thorium itself, evolved an intense light when heated in the Bunsen flame. This observation led him to soak a filament of cotton in a solution of thorium nitrate and to try the effect of heating this in the non-luminous flame. Instant success crowned his experiment; the cotton burned away, leaving a coherent residue of thorium oxide which glowed with brilliant whiteness on heating. From this it was but a short step to the preparation of mantles as we at present know them, by dipping a "stocking" of cotton or ramie in the solution, thus obtaining the maximum surface of luminescence. Experiment showed him that in order to produce the most efficient light an admixture of one per cent. of cerium oxide to the thorium oxide was necessary, and this mixture has never been improved upon. It was not long before he was manufacturing mantles on a commercial scale, and some idea of the present magnitude of the industry may be gathered from the fact that in Germany alone no less than 150,000,000 of such mantles are yearly turned out. They are, of course, manufactured on a like scale in other civilised countries.

"The field of chemical experimentation has in the last decade been widened to an extraordinary degree by the ease with which it is possible to obtain very high and very low temperatures. High temperatures can now be obtained by means of electric furnaces, with which temperatures up to

3000° are easily produced. Low temperatures may be obtained by means of liquid air. This commodity can now be purchased in Berlin at the price of a wine of medium quality, that is to say, at 1*s.* 9*d.* per litre. For this we are indebted to your Majesty, who invited Professor von Linde, of Munich, to erect here one of his large machines for the liquefaction of air. You will understand how indispensable this liquid has become when I tell you that in the laboratories of the University of Berlin several litres are daily consumed for scientific purposes.

"Far more effective is liquid hydrogen, which affords a temperature lying 60° below that of liquid air. The boiling point is as low as −252·6° C.,—only 20·4° above the absolute zero. It cannot, however, yet be purchased in Berlin ; in fact, it cannot be obtained here at all. I am nevertheless able to show it to you. This preparation comes from the physical laboratory of the University of Leipzig, where it was prepared this morning and transported here with great care. I will now transfer a small quantity from the oddly shaped container into a transparent glass vessel, and demonstrate the lowness of its temperature by immersing in it a glass tube sealed at the bottom. On removing the tube it is seen to be filled with a white solid resembling snow ; this is solid air ; you will see that, when once removed from the cooling liquid, this solid melts after a few moments.

"When the Kaiser-Wilhelm Institutes for Chemistry are once in full swing, we shall, I hope, no longer be obliged to travel to Leipzig every time we want some liquid hydrogen.

"Liquid hydrogen was prepared for the first time about twelve years ago by Professor Dewar in the famous laboratory at the Royal Institution in London. But the costly experiments necessary for its production were rendered possible only by the liberal means which Dr. Ludwig Mond, the great benefactor of chemistry, placed at his disposal. Dr. Mond, moreover, has not forgotten his German Fatherland and German Science. He bequeathed to the University of Heidelberg, where he had studied, the sum of £50,000 for chemical and physical research, and several years ago he endowed the State-supported chemical institute which we had planned with the sum of £10,000."

Apart from such scientific purposes, liquid air is gradually acquiring great industrial importance. In the modern processes for the manufacture of oxygen—which is employed in many of the arts for various purposes, but particularly for oxy-hydrogen and oxy-coal-gas flames—the atmospheric air is liquefied, and the resultant liquid fractionally distilled. By this procedure the nitrogen first boils off, being for the most part rejected, while the oxygen, which boils at a slightly higher temperature, can be separately collected in a pure state. The residue from which the oxygen

and nitrogen have been distilled is a mixture of the inert gases of the atmosphere, consisting principally of argon. The "Société Air Liquide" of Paris is thus enabled to place large quantities of these residues at the disposal of scientific investigators—in this way repaying Science in kind for the benefits it has conferred.

The intense cold of liquid air—boiling as it does at a temperature some 200° C. below that of the atmosphere—renders it destructive to living flesh when brought into contact therewith. The painful effects usually attributed to hot bodies are all reproduced by the intense cold of liquid air, for it matters not whether the rapid transmission of heat through the tissues takes place in an inward or in an outward direction. Liquid air has for this reason found successful application as a cauterising agent, and a case is recorded of the excision of a cancer by its means.

Liquid air, consisting of oxygen in a highly concentrated form, permits of the rapid combustion of substances brought into contact with it. A strip of steel, the end of which is heated and plunged into this concentrated oxygen, burns with intense brilliancy. In the same way, a mixture of liquid air with finely divided carbon, in the form of cotton wool or coal dust, explodes with extraordinary violence when ignited. Advantage has been taken of this fact by utilising such a mixture as an explosive in coal mines. The method is an improve-

ment on the use of dynamite, in that after the lapse of a few minutes the liquid air has completely evaporated, leaving an innocuous non-explosive residue, so that the accidental explosions of unfired charges, so lamentably frequent in the employment of dynamite, are thereby avoided.

But the atmosphere has been forced to render even more valuable products. For many years attempts have been made to prepare "fixed" nitrogen from the air—nitrogen in some form which can be applied directly to industrial and agricultural purposes—either in the oxidised form (nitric acid, nitrates, nitrites) or in the reduced form (ammonia and ammonia-yielding substances). The actual fixation of nitrogen dates from the time of Cavendish, who submitted air to the action of the electric spark in the presence of alkali, thus obtaining nitrates and nitrites, but only recently has it become possible on a commercial scale. The oxidation of nitrogen was first carried out on a moderately large scale in 1897, by Lord Rayleigh, who obtained considerable quantities of nitric acid from air by means of the electric discharge. Since that time the development of the subject has progressed by leaps and bounds.

The importance to humanity of some method of utilising the nitrogen of the atmosphere cannot be estimated too highly. Until recently, practically all the nitric acid and nitrates employed in the arts and in agriculture were derived from the nitrate-beds

of Chile, and it is not to be assumed that these deposits are inexhaustible. In 1825 one shipload of the sodium nitrate was exported with the intention of employing it for the manufacture of gunpowder; but it was found to be too deliquescent for this purpose, and was therefore thrown into the sea. In 1840 Liebig put forward the principle of artificial replacement of substances removed from the soil by the crops, recommending the use of nitre as a chemical manure. At that time a few thousand tons were yearly removed from the nitrate-beds; but the practice has undergone so rapid a development that at the present time over two millions of tons are each year exported from South America. At this rate the beds will be exhausted in less than thirty years.

The world has therefore looked, and not looked in vain, to the chemist to solve this problem. For as three-quarters of the nitrate dug up from the deposits in Chile is employed as chemical manure, without it the supply of food would be hopelessly inadequate to meet the needs of the inhabitants of our globe. The present generation would indeed be betraying its trust were it to consume the total store, acquired in millions of years, without providing for the nourishment of posterity. But there need be no fear of such a calamity, as the following words of Professor Fischer indicate :—

"The direct production of nitric acid from air by means of a powerful electric discharge has reached

the stage of large-scale manufacture. In Norway at the present moment gigantic works, by the side of a mighty waterfall, are in course of erection by German factories in conjunction with Norwegian engineers, and supported by German and French capital.

"Synthetical saltpetre is already on the market, and German dye factories derive a considerable portion of the nitrites necessary for their work from the same source.

"The strikingly original process devised by Professor A. Frank and Dr. N. Caro in Charlottenburg for the preparation of calcium cyanamide from calcium carbide and atmospheric nitrogen came somewhat earlier into practice.

"And now a third process, based upon the direct combination of atmospheric nitrogen and hydrogen to form ammonia, has been announced. Professor Haber, of Karlsruhe, by an ingenious application of the laws of physical chemistry, has succeeded in obviating the difficulties which hitherto have rendered this synthesis impracticable. The well-known Badische Anilin- und Sodafabrik at Ludwigshafen-am-Rhein has taken over his patents and technically perfected the process to such a degree that synthetical ammonia will in all probability shortly be placed on the market.

"The greater the number of such processes and the keener the competition which they excite, the greater is the benefit to the consumer. In the case

I have just mentioned this has an especial significance, as the bulk of technical nitrogenous substances are employed in agriculture for artificial manures.

"In the opinion of high authorities, German agriculture could easily consume twice, nay thrice, the amount of nitrogenous material at present employed for this purpose, were only the price to fall to a corresponding degree. In such a case it is possible that the crops would increase to such an extent that Germany could be independent of foreign countries with respect to agricultural produce. A task of great national importance has thus been set to chemical industry.

"This last process, the synthesis of ammonia, possesses the advantage that no electricity, merely heat, is involved. In other words, all that is necessary is fuel, a commodity of which Germany has ample store. Furthermore, it is to be noted that the cost of production depends only on the price of hydrogen, which, together with the inexpensive atmospheric nitrogen, serves as raw material. The problem of producing hydrogen at moderate cost has already been solved by chemical industry, owing to the great interest recently taken in airships. In this way, the truth of the old saying is established—that all industries affect one another, and that improvements in one field may occasion fertile results in totally remote spheres of activity."

Much could be written concerning the series of successes following upon Liebig's suggestion of employing artificial manures, whereby the nitrogen removed from the soil in the form of crops is replaced by chemical means. It need merely be said that these have almost universally become a necessity to the progressive farmer, and that artificial manures to a value of over five millions sterling are annually produced in Germany alone. A striking instance of the achievement by science of a double purpose is afforded by the employment of sewage in agriculture. As sewage disposal is rapidly becoming a matter of national importance it may warrant a slight digression.

A great advance in the sanitary conditions of towns was effected during the nineteenth century by the introduction of drainage systems. But we are now faced with the serious problem of sewage disposal. It is well known that the organic life present in rivers is capable of destroying the impurities introduced into the waters by the drainage of towns, provided that a clear run of sufficient length is afforded. But the increase in the quantities of sewage discharged into the rivers passing through great cities such as London has shown that when the pollution has reached a definite state of concentration, the bacteria destructive to such impurities are themselves destroyed, the natural cleansing of the stream being then unable to proceed.

We stand at present upon the threshold of the solution of the problem. In cases where the towns are built upon a sandy soil, the sewage, instead of being a source of loss to the community, can be converted into a valuable asset by the installation of sewage farms. Sewage farms have long been worked in England and other countries with greater or less success, though with pronounced profit only when an extremely porous soil is present. Thus in Berlin the drainage of the entire city is pumped up to such farms, established on the permeable soil of the Mark, where crops far heavier and more frequent than at ordinary farms are produced. The water, after passing through the sandy ground, appears as a clear effluent of such purity that it is possible to drink of it with perfect safety. All the poisonous matter originally present has been absorbed by this gigantic filter, and furnishes the nutriment for the flourishing crops. This method of sewage disposal is of course impracticable on clay soils, and in such cases some direct method of destruction must be applied. Among these are comprised various chemical and electrochemical processes, as well as the recently-discovered and promising method based on the action of a "denitrifying" bacterium, which destroys organic matter of animal origin with evolution of elementary nitrogen. A Royal Commission has been engaged for some years upon the question, and it is anticipated that a satisfactory solution will before long be reached.

Much interest attaches to the process of Frank and Caro for the production of calcium cyanamide, which is now manufactured in large quantities for use as a chemical manure. It is prepared by heating calcium carbide to a very high temperature in presence of atmospheric nitrogen.

Calcium carbide, employed as a starting material, has an instructive history. It was discovered in 1862 by Wöhler—the same chemist who was the first to synthesise a purely animal product, urea,—by treating metallic calcium with carbon at a high temperature. The substance was in those days regarded merely as a chemical curiosity, owing to the great expense of its preparation, and its discovery was soon forgotten by the scientific world.

In 1892 calcium carbide was rediscovered by an American chemist named Willson, and by the celebrated French investigator Moissan, working independently. Willson, in the course of some experiments with the electric furnace, had heated a mixture of coke and lime, in the hope of producing metallic calcium. On opening the furnace he obtained a grey fusible mass, which obviously contained no metallic calcium and was of no apparent value. As luck would have it, this despised block of matter, after being removed from the furnace, fell into a bucket of water. Torrents of an evil-smelling gas were at once evolved. This gas, on examination, was found to burn with a brilliant flame and was before long proved to be almost

pure acetylene. We have only to consider the number of uses to which acetylene is now put—such as automobile lamps, oxy-acetylene welding, and the illumination of private houses—to realise the extent of the industry based upon this accidental outcome of scientific experiment.

The electric furnace has likewise produced for us substitutes for the hardest materials of nature—carborundum and artificial diamonds. Carborundum, which is now extensively employed as a substitute for emery in whetstones and grinding wheels, is prepared by heating a mixture of silicon and carbon to the temperature of the electric arc, and appears as a dark crystalline body, the surface of which exhibits a multitude of iridescent colours. Artificial diamonds, although of less technical importance, are of considerable scientific interest. They were prepared by Moissan by heating soft charcoal enclosed in an iron cylinder in a carbon crucible heated by an electric arc. The white-hot molten iron, in which the charcoal had dissolved, was then plunged into water, so that the outside was the first to cool. In solidifying, the shell thus formed subjected the interior molten core to an enormous pressure. This, on cooling, deposited the excess ot carbon in the form of minute crystals, which, though black in colour and valueless as gems, possessed all the chemical and physical attributes of diamonds. Such diamonds may find useful application in rock drills, where the small size and black hue are no disadvantage.

High temperatures are now obtainable not only from electricity. By the "Thermit" process, recently introduced, temperatures at which iron runs like water can readily be reached without any cumbrous plant whatsoever. By igniting a simple mixture of aluminium powder and iron oxide a reaction sets in which evolves so much heat that the mixture soon glows with intense brilliancy. Liquid iron is produced, together with a slag of alumina. Welding can thus be effected with great ease and a minimum of appliances. An interesting feature of this process is the high purity of the resultant iron; and by modifications in which oxides of other metals are employed, such metals as chromium, tungsten, manganese, vanadium and tantalum can be prepared in a state of purity never before attained.

An elegant process, by which the metals nickel and cobalt are separated and prepared in a state of chemical purity on a commercial scale, is that now employed by the Mond Nickel Company. On passing producer gas over heated ores containing these metals, the nickel and cobalt combine with the carbon monoxide present in the gas, with production of volatile liquids termed nickel carbonyl and cobalt carbonyl. These liquids are collected by condensation, separated by fractional distillation, and decomposed again by heat, with regeneration of the pure metal and carbon monoxide. This process has supplanted all others owing to its extreme simplicity and cheapness.

Iron has recently been produced in a condition of purity even higher than that afforded by the Thermit process. This is the "electrolytic iron" obtained by a novel application of electrolysis devised by Professor Franz Fischer in Berlin. It is prepared in the form of tough shining plates, of any desired shape, according to the conformation of the electrode upon which it is deposited from the solution. In consequence of its extraordinary purity its magnetic susceptibility is greatly in excess of that of any other kind of iron hitherto known. An electric motor of any design develops more than twice the original horse-power when the ordinary armature and magnets are replaced by those constructed of electrolytic iron. This invention therefore bids fair to create a revolution in electrical industries.

"Our present-day material civilisation," Prof. Fischer goes on to say "is to a great extent founded on the rapid utilisation of the fossilised combustibles anthracite and brown coal. But posterity will not fail to reproach us with having grievously squandered this valuable material; for in the conversion of the heat of combustion of coal into energy in the ordinary way by means of steam engines, more than eighty-five per cent. of the work potentially contained in the coal is lost. This loss may, however, be appreciably lessened by suitable chemical treatment of the coal. If the coal be first converted into combustible gas—so-

called power gas—and this then consumed in a gas engine, the output of useful power is treble that developed in a steam engine. Valuable by-products—ammonia and tar—can, moreover, be recovered, and, indeed, the methods hitherto employed for the production of power gas are in many respects capable of improvement. I therefore deem it possible that special institutes will at some future time be founded in the centres of the coal districts, where these important problems can be investigated with the aid of all the methods known to science.

"Fossilised combustibles, which owe their origin to the vegetable kingdom, form a connecting link between mineral and organic substances. Organic chemistry vastly surpasses inorganic chemistry in variety of methods and products. Small wonder, for it embraces all those complicated chemical bodies which occur in animal and vegetable life. The number of organic substances accurately investigated may to-day be estimated at the huge figure of 150,000, and every year eight or nine thousand more are added to the list. We may therefore reckon that at the close of this century organic chemistry will comprise the entire gamut of substances found in the animal and vegetable kingdoms.

"This rapid increase is wholly due to organic synthesis. From the few elements occurring in organic chemistry, of which carbon predominates,

all these compounds are built up, much as an architect produces the most diverse edifices from the same form of brick.

"Synthesis in organic chemistry had its origin eighty-two years ago, at Berlin, in the synthetical production of urea by Friedrich Wöhler, and it has found its greatest field of activity in Germany. It stands no longer in fear and trembling of the complicated constituents of the living organism. I shall demonstrate this fact by discussing the three classes of substance predominating in organic life: the fats, the carbohydrates, and the proteins. The synthesis of fats was effected two generations ago by M. Berthelot in Paris. The first synthetical carbohydrates—grape sugar, fruit sugar, etc.—saw the light twenty years ago in Würzberg; and the methods for the synthetical building up of albuminous substances have been worked out during the last ten years in the laboratory of the University of this city. I am therefore able to show you one of these products. It is the most complicated substance ever evolved by synthesis, and has so long a name[1] that I do not venture to pronounce it here. The amount is certainly small, and, as you will perceive later, the beakers and flasks of the scientific investigator are minute when compared with the vats employed by the chemical manufacturer. This relative difference in size may

[1] Laevoleucyltriglycyllaevoleucyltriglycyllaevoleucyloctaglycylglycine.

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be remarked also, in the comparative wealth of these two classes of men. This synthetical protein, like the mesothorium of Dr. Hahn, is anything but cheap. The starting materials for its synthesis cost about £50, and the labour involved in its preparation must be put at an even higher figure. It has therefore not as yet made its appearance on the dining-table. It is, in fact, nothing but a chemical curiosity. But you must bear in mind that what is to-day merely a curiosity may to-morrow be of the greatest value. Chemistry affords numberless illustrations of this.

"Through such things as these proteins, carbohydrates, and fats, organic chemistry is brought into close touch with the biological sciences; for the entire metabolism in the living organism is merely a sequence of chemical transformations which these substances undergo. Chemistry is thus called upon to partake in the solution of the great riddles of life; nourishment, growth, reproduction, heredity, age, and the manifold pathological disturbances of the normal state. It is not surprising that the keenest activity exists in these interesting fields of work, and we may safely hope that provision will be made for biological research in the new Kaiser-Wilhelm institutes.

"The example given by the magnificent institute here in Berlin for the study of the problems of the industries connected with fermentation, in which the results of scientific research meet the practical

requirements of brewers and distillers, serves to show how fruitful can be the collaboration of biologists and chemists. This institute has contributed its share to the small exhibition here this evening by a series of beautiful mould cultures and yeast preparations.

"Moreover, chemical and many other industries have derived great benefit from organic chemistry. A few examples from recent times will illustrate this fact.

"The most widely distributed of all the carbohydrates is cellulose, of which cotton and linen are entirely composed, and which is the chief constituent of wood and plant fibres. And what a variety of articles is nowadays manufactured from cellulose! Paper, collodion, celluloid, photographic films, smokeless powder, artificial silk, artificial hair, artificial leather.

"Paper, in this Paper Age, is not a substance which requires exhibition here; the same may be said of celluloid and collodion. I have not brought here samples of smokeless powder and the other high explosives derived from cellulose, as the Ministry of Education seems a place far too peaceful for their exhibition. But you see before you artificial silk, horsehair and films, in diverse and magnificent array. These come from the works of Fürst Guido von Donnersmarck; and not to omit mention of his competitors, I here show you some photographic films manufactured by the

Berlin Anilinfabrik, which, unlike the ordinary variety, burn only with the greatest difficulty. All these products have been prepared by ingenious combinations of chemical and mechanical processes."

The history of artificial silk is an interesting one. It is a step in that line of artificiality which constitutes the progress of man. A change which has completely transformed human industries, and to which the principal features which distinguish civilisation from savagery are traceable, is the substitution of an artificial for a natural product.

After the discovery of nitrocellulose (pyroxylin, gun-cotton) by Schönbein and Böttger in 1846, repeated attempts were made to produce artificial silk from this material, but without success until Count Chardonnet of Besançon devised about the year 1885 his process of drawing fine threads of collodion through water, obtaining by this means fibres sufficiently tough to weave. Owing to the highly inflammable nature of nitrocellulose the danger of fire rendered the resulting fabric unsafe to wear. To remedy this drawback, Chardonnet adopted a process of "denitration," by which the material was relieved of this dangerous tendency. In addition to this outstanding advantage over the celluloid product not thus denitrated, the new material possesses the property of being readily dyed. It bears every physical resemblance—with the one exception that it burns rather more freely

—to natural silk, and many people buy large quantities of it under the impression that it is the genuine article of animal origin.

The chemist has long recognised that it is impracticable to filter a solution of copper hydroxide in aqueous ammonia by the usual methods, owing to the ready solubility of the filter paper in this mixture. This fact has been utilised in the manufacture of the well-known commodities termed "Willesden Paper," "Willesden Cloth," and "Willesden Canvas." In these materials the surface of the texture has been dissolved in ammoniacal copper hydroxide, and the solution allowed to set, thus rendering the paper or canvas impervious to water and free from any tendency to rot. Of late years a process has been developed whereby such a cellulose solution is forced through glass capillary openings, and the resulting stream coagulated to a tough thread by passage through a weak acid. After further washing and subsequent drying, these threads can be spun and woven into textures which are distinguishable from real silk only by chemical tests. Enormous quantities of this material are now manufactured in Germany and France.

Another substitute for silk which is now extensively employed has developed from the old process of "mercerisation." It has long been known that on treating cotton with an alkaline solution a shiny and resistant surface is imparted

to the fibre. Such mercerised cotton, in its superior qualities, is largely employed as a substitute for silk under the name of "spun silk." If the process of mercerisation be carried further, the celluloid swells up into a gelatinous mass, which remains, however, insoluble in water. In 1892 Cross, Bevan and Beadle made the striking discovery that if to such a mixture a small proportion of carbon bisulphide be added, the cellulose enters completely into solution, yielding a viscous liquid. For this new substance, which they termed "Viscose," they obtained a patent. For a variety of unexpected reasons the invention failed to find immediate and permanent application, and in 1906 it was accorded the rare distinction of an extension of the patent for a further period of five years. During this last lustrum, however, it has been found possible to produce from it fibres from which textures closely resembling silk can be woven, and the cheapness of the process gives it so great an advantage that it may confidently be expected to replace entirely, not only the natural silk, but also the less inexpensive silk substitutes at present manufactured.

Lastly, a comparative failure must be recorded. Cellulose acetate, which at first sight appeared to contain the germ of a promising artificial silk industry, has met with but little success in this field, owing to the expense of its production and the brittle nature of its fibres.

It need scarcely be stated that all the substitutes

for silk above enumerated bear not the faintest resemblance to the natural product in chemical composition. Cellulose, the parent substance of all these, is a carbohydrate, a member of the class to which belong starch and the sugars, while true silk is to be grouped among the proteids, of which multitudinous family albumen and gelatine are typical members. The resemblance between silk and its substitutes is therefore to be found exclusively among the purely physical characteristics.

The subject of photographic films is intimately connected with that of artificial silk. Until the year 1887 photography was only for professional photographers and those amateurs who had sufficient enthusiasm to carry with them on their expeditions some pounds of glass plates. The advent of nitrocellulose opened up the fascinating field of photography to all. It is certainly true that before the introduction of celluloid films nitrocellulose was employed in the form of wet collodion plates, but these, as photographers of long standing will recollect with a shudder, were an abomination, from which we were mercifully relieved by the introduction of gelatine dry plates. With the invention of the photographic film the art of "snapshotting" first began to assume the position which it at present holds among the resources of the observant traveller.

Celluloid films, first introduced by Eastman in the year 1887, are manufactured by preparing a

viscous solution of nitrocellulose in some such solvent as acetone or amyl acetate, together with a softening agent—usually camphor—and pouring this evenly on to a smooth surface. The solvent volatilises, leaving a lustrous film, which is thereupon stripped from the supporting surface. The film is then coated on one side in a non-actinic light with sensitised gelatine—containing silver bromide in emulsion—and cut up into suitable strips. Owing to the strain exerted by the shrinkage of the sensitive emulsion, the films so prepared tend to curl up into tight rolls after development and drying. This defect has been remedied of recent years by coating the reverse side of the film with a layer of non-sensitised gelatine. The stress is thus equalised on the two sides, and flat films result.

An important branch of the photographic industry, assuming enormous proportions at the present time, is that due to the perfecting of the cinematograph. In the reproducing apparatus a narrow film, of which the standard length is no less than 400 feet, and covered with a multitudinous sequence of small individual photographs, is passed by rapid jerks between an electric arc light and an enlarging lens. Owing to the intense heat of the arc and the highly inflammable nature of the celluloid film, it is absolutely essential that the film should not remain stationary for more than a minute fraction of a second at a time, and hence

any breakdown of the mechanism may lead to disastrous fires. This danger was exemplified by the deplorable catastrophe in Paris in May 1897, in which no less than 132 persons lost their lives. The need for non-inflammable films has therefore been urgent. Such films were soon invented, the base employed being acetate of cellulose, discovered in 1879 by Franchimont in the course of a scientific investigation on derivatives of cellulose, and shown by Cross and Bevan in 1894 to be suitable for the manufacture of films and filaments. Owing, however, to the increased cost of manufacture and the diminished durability of these films as compared with the celluloid product, acetyl cellulose films have met with only transitory success in this field, but other derivatives of cellulose, of different chemical nature, are rapidly coming into employment for this purpose. It is thus seen that at every turn scientific research responds to the appeals of industry.

A further development of the photographic art is colour photography, which has recently entered the domain of the amateur. The three-colour process has long been known, but owing to the fact that its component images require superposition in exact register, it has proved to be adaptable only to the production of chromolithographic prints.

In 1906 the brothers Auguste and Louis Lumière patented their process for single-plate colour

photography, the first to prove a practical success. In this the plates are prepared by staining grains of potato starch with the three primary colours—red, yellowish-green and blue—scattering these evenly on a glass plate coated with an adhesive varnish and pressing them flat in order to ensure as close a contact between them as possible. The interstices are then filled with a black pigment. After varnishing this microscopic mosaic of colours, the surface is coated with a panchromatic sensitised emulsion. It may be noted that the panchromatisation of emulsions is in itself a complicated process, involving the fruits of much chemical experimentation.

After exposing the plate from the back, through the screen, and developing in the ordinary way, the free silver forming the negative image is dissolved out by an acid solution of permanganate and the residual unchanged silver bromide fogged by light and again developed. By this procedure a positive image is obtained, in which the true colours of the original appear on the plate.

One of the disadvantages of this process is the necessity of degrading the entire effect of the image by the admixture of the black pigment. Plates and films are now manufactured in which the coloured starch grains are replaced by a "raster" of closely-ruled hatched lines of the primary colours. It is interesting to note that MM. Lumière, after overcoming the manifold difficulties

of their colour plate, have placed the manufacture in other hands, and again turned to pure scientific research.

The colouring matters involved in the preparation of colour-plates are themselves the products of one of the most important chemical industries. Here, again, we see the foundation of a vast field of manufacture based entirely on abstract chemical experimentation.

The most important branch of the dyestuff industry finds its raw materials in the products of the distillation of coal. In 1856 the late Sir William Perkin, while examining the impure aniline available at that date, was led to try the effect of oxidising agents upon it. He was instantly rewarded with an uninviting purple precipitate, which most of the chemists of his day would have at once thrown into the sink. Yet such was his perseverance that from this unpromising product he was able to prepare the first of the protean series of coal-tar dyes: "Mauvine." It was not long before he was preparing several such colouring matters on the manufacturing scale. Mauvine itself, though the first, found no very wide application, and on the withdrawal of the penny stamps of that colour, some ten years ago, its employment practically ceased.

It stands to the lasting discredit of England that shortly after Perkin had retired from the manufacture of these dyestuffs, and had re-entered the

field of purely scientific activity, the industry was transferred in its entirety to Germany. The factory at Greenford in which the first coal-tar colours were manufactured remains to this day deserted. Were adequate interest taken in the welfare of research in this country there should be no reason why such industries should migrate to the other side of the North Sea so soon after their initiation. Artificial preventatives, such as the new Patent Act, do more harm than good to inventors and to industry. Furtherance of scientific research, not industrial palliatives, is required. The smokeless stacks of the Greenford ruin may thus stand as a monumental reminder of the neglected claims of science.

Hofmann, one of the greatest of organic chemists, in his report on the Exhibition of 1862, made the following prediction :—

> "England will, beyond question, at no distant day, become herself the greatest colour-producing country in the world, nay, by the strangest of revolutions, she may, ere long, send her coal-derived blues to indigo-growing India, her tar-distilled crimsons to cochineal-producing Mexico, and her fossil substitutes for quercitron and safflower to China, Japan, and the other countries whence these articles are now derived."

Hofmann's prediction was certainly correct from a scientific point of view ; but England has not

justified her promise, and it is Germany which sends the synthetical dyestuffs to those countries whence the corresponding products of nature were formerly exported.

Hundreds of synthetic dyes are at present on the market, and the value of the dyestuffs yearly produced in Germany approximates to fifteen millions of pounds sterling. The manufacture has attained such importance that complete courses of lectures on the subject are delivered to chemical students in the German universities.

In addition to the production of entirely new dyes, synthetical organic chemistry has been able to reproduce many of the natural colouring matters long in use, and this, moreover, at less cost. The first important natural dyestuff to be thus obtained was indigo, its synthesis being effected by von Baeyer in 1882. "This synthetical product," Professor Fischer continued, "is not only much purer in composition and colour than the natural dyestuff, but also considerably less expensive. On this account the cultivation of the indigo plant in India has diminished to one-sixth of the original extent, and will in all probability soon disappear altogether. Woollen and cotton goods are now dyed with German indigo even in Asia, to which continent a quantity of indigo worth no less than £1,900,000 was exported in the year 1909."

It is but right, however, to point out that the recent work of Bloxam and his collaborators has

demonstrated the possibility of recovering from the leaf a yield of indigo increased to such a degree that the cost of production is, if anything, less than that of the synthetical product. Moreover, natural indigo is stated by some authorities to possess certain benign impurities which render it more suitable for dyeing purposes. It may therefore come to pass that the great indigo plantations in India once again blossom forth under scientific guidance.

Another synthetic dyestuff which has almost entirely replaced the natural product is alizarine. First synthesised in 1869 by Graebe and Liebermann, by a happy combination of insight and good fortune, it rapidly came into use in place of the madder formerly so extensively grown. At that period the value of the madder annually produced in France amounted to £1,700,000. After the introduction of alizarine the price of the root fell to one-fifth its former amount, resulting in an immediate increase in the activity of the dyeing industries. The plantations in France which formerly produced the madder root are now devoted to more lucrative crops. Madder is at present cultivated only in the Caucasus and in India, in which countries, owing to some peculiarity of the soil, the root provides more alizarine than in France.

"While on this subject, I may refer to the two most important colouring matters of animal and vegetable life, chlorophyll and hæmoglobin. The former plays an important part in the chemical

process upon which all life depends—I refer to the conversion of the atmospheric carbon dioxide into sugar, which takes place in green leaves under the influence of sunlight. The red pigment in the blood fulfils in our own bodies the important function of transporting the oxygen from our lungs to the tissues, thus rendering possible that process of combustion which forms the basis of our bodily and mental strength.

"I here show to you," Prof. Fischer proceeded, "two specimens of pure chlorophyll, one of which is crystalline. I owe these rare preparations to Professor R. Willstätter, of Zürich, who of recent years has been studying this colouring matter with remarkably successful results. Hæmoglobin also has lately been thoroughly investigated in Stuttgart and in Munich, and the remarkable conclusion has been drawn from these investigations that chlorophylll and hæmoglobin are closely related. This fact thus denotes a species of consanguinity between the animal and vegetable kingdoms. This must, however, be of great antiquity—that is to say, to date from remote times when the animal and vegetable kingdoms were as yet not distinct."

We have just seen how two great natural industries—the cultivation of the indigo and the madder plants—have been forced to the wall by the synthetical manufacture of the requisite components of their produce. Temporary disturbance is no doubt occasioned to capitalists, merchants and operatives, by these reorganisations of trade,

but to imagine such changes harmful would be as unreasoning as was the action of the Blackburn mob of cotton spinners who broke in pieces Hargreaves' spinning jenny.

At the present day we are witnessing the progress of a revolution destined to destroy one of the greatest industries in existence: the cultivation of indiarubber, which is yearly consumed to the value of thirty-five millions sterling. The seed of this industrial revolution was sown so long ago as the year 1837, on the discovery of a volatile liquid —at that time to all appearances merely a chemical curiosity and of no technical importance—termed "isoprene" by its discoverer, Bouchardat, who indeed found that it would be partially converted into a rubber-like product. But as the general principles of organic chemistry were at that time but little known, for years no particular attention was given to this substance, until it was found that on merely allowing it to stand by itself it underwent a spontaneous chemical change (polymerisation), with formation of dipentene, a member of the turpentine family and closely connected with oil of lemon. Further study was therefore accorded to this peculiar property of isoprene, and in 1892 Sir William Tilden showed conclusively that under certain circumstances it could be induced to yield indiarubber. As, however, the preparation of isoprene involved either the destructive distillation of indiarubber itself or a synthetic process even more costly, this discovery was little more than an

indication of the possibility of synthesising this valuable product.

Matters remained in this condition until the year 1909, when, after long experimentation, two chemists of the Elberfelder Farbwerke, Drs. Hofmann and Coutelle, devised a process by which isoprene could be manufactured on a cheap commercial scale. The problem then consisted merely in ascertaining the most satisfactory method of converting the isoprene into indiarubber. Final solution of this problem has as yet not been attained; nevertheless, indiarubber has been produced in considerable quantities merely by heating the liquid in sealed vessels. It is extremely probable that this method will form the basis of the final process; research is at present being directed towards the question of best conditions. "That the product," Prof. Fischer went on to say, "is really indiarubber has been definitely established by the scientific investigations of Professor Harries in Kiel, a high authority on this subject, who has since independently devised another process for the same purpose.

"When synthetic chemistry has once entered such a field, it is not confined to the particular product occurring in nature, but is able to bring forth a whole series of similar substances. It is therefore not surprising that other rubber-like substances should have been prepared, not from isoprene, but from similar liquids; such as dimethylbutadiene. Such products are termed homologues.

They possess properties closely resembling those of indiarubber, but differ slightly in chemical constitution. It is, as yet, not decided which of these synthetical substances forms the most suitable substitute for indiarubber. The same applies to the far more important question of cost of production. But when one considers the fate of natural indigo, of madder, and of other natural products, one may hope to see synthetical indiarubber gradually enter into successful competition with the naturally-occurring commodity."

Artificial substitutes for a similar product, resin, and for amber, a petrified resin, are also now manufactured commercially. Artificial amber was first prepared from a mixture of formalin and carbolic acid, by Story in England in the year 1905. Since that time an American chemist, Baekeland, has developed this process in its technical aspect; and the product, termed "Bakelite," manufactured by his company, is employed for the production of such articles as combs, necklaces, and cigar-holders.

Camphor is now being synthesised on a large scale from turpentine and similar products. This synthesis is not of a particularly striking nature, as the chemical constitution of camphor is closely related to that of the chief constituent of the oil of turpentine. Nevertheless, the utilisation of a cheap material for the production of one more valuable is instructive, especially so in this case, as many unsuccessful attempts to effect this transformation

had been made before a process which was even a laboratory success was hit upon. Camphor, moreover, had been synthesised on a small scale from simpler substances before its production from turpentine was shown to be possible. With the advent of the technical synthesis of camphor, and the consequent fall in price, the monopoly of this commodity, held by the Japanese after the annexation of Formosa, was broken down.

In addition to camphor, which indeed is by no means employed exclusively as a medicament, a host of other drugs is now prepared synthetically on a commercial scale. A few naturally-occurring drugs, such as caffein, have been reproduced synthetically, but by far the majority of these are new compounds, not met with in nature, which have been discovered by chemical research, and whose valuable medicinal properties have been established by physiological research.

"In this bottle," Prof. Fischer proceeded, "you see a white powder—veronal—which is a hypnotic largely employed at the present day. It is in no way connected with the older vegetable narcotics—opium, etc.—but is entirely a synthetical product. One-tenth of this quantity would suffice to send this entire gathering into a peaceful slumber. But should the mere demonstration of this soporific—acting in conjunction with this lecture of mine—take effect on any susceptible persons present, there is no better remedy than the cup of tea which we are

to enjoy later, for tea contains a chemical substance which stimulates the heart and nervous system. This is also present in coffee, in which it was discovered ninety years ago by Runge in this country. The humorously inclined discoverer termed it 'Kaffebasee,' [1] which name, however, was afterwards changed to the more distinguished 'caffein.'

"Caffein was first synthesised in the laboratory of the University of Berlin exactly fifteen years ago, this synthesis leading to its manufacture on a large scale. It is prepared in large quantities from uric acid, a constituent of guano, but has undergone such a complete chemical transformation and purification that it no longer possesses the unpleasant characteristics of the raw material from which it is manufactured. The chemist may therefore apply to such substances the remark made by the Emperor Vespasian concerning the tax-money which came to him from an unclean source: *non olet* (it has no smell).

"Caffein is the active principle of tea, coffee, kola and Paraguay tea (maté), so that, after alcohol, it is certainly the most widely employed stimulant. When organic chemistry succeeds in the task, an entirely possible one, of synthetically reproducing the aroma of tea and coffee, there will be nothing to hinder the artificial preparation of these beverages; and when the Minister of Education invites

[1] The word has the double meaning of "coffee base" and "gossip."

a gathering to celebrate the fiftieth anniversary of the Kaiser-Wilhelm Society, the repast, I hope, will comprise synthetical tea.

"Organic synthesis is not limited to vegetable products only, but embraces with equal fearlessness substances of animal origin. An instructive example of this may be found in a remarkable compound, adrenalin, which is formed in our own bodies in the suprarenal glands, and which plays an important part in the regulation of the blood pressure. Shortly after its isolation[1] in a pure condition from these glands, Dr. F. Stolz, chemist to the dye factory at Höchst, was able to synthesise it from constituents of coal-tar. This synthetical product has now been placed on the market by the Höchst firm under the name of 'Suprarenin.' A very dilute solution of the substance causes powerful contraction of the blood vessels, and consequent dispersal of blood from the tissues. A skin surface well charged with blood—as, for instance, a red nose—is instantly rendered quite pale on painting it with such a solution. Unfortunately, the colour is not evenly discharged, owing to the varying permeability of the epidermis, and as the action of the drug soon ceases, with return of the original redness, adrenalin is not suitable as a cosmetic. On the other hand, it finds most useful application in surgery, as by its means certain incisions can be made without loss of blood;

[1] The work of Takamine, a Japanese chemist, in 1901.

this is found particularly convenient for operations on the eye, mouth and nose."

Other drugs, prepared during the course of chemical research without reference to their possible utilisation, but since shown to possess antipyretic, analgesic, or similar physiological actions, are acetanilide (antifebrin), phenyl salicylate (salol), acetylsalicylic acid (aspirine), phenacetine, antipyrine, and many others. Certain of these, as for instance antipyrine, have proved of immense value to mankind, and incidentally to the chemist fortunate enough to discover the substance and at the same time to realise its pharmacological importance. The majority of alkaloids, such as quinine, cinchonine and nicotine, have already been synthesised in the laboratory, although this has not yet proved remunerative on a commercial scale.

A medicament which has recently formed the subject of much discussion, and which bids fair to contribute a rapid cure for one of the most terrible scourges of mankind, is that originally known as "Ehrlich-Hata," now as "Salvarsan," but most familiarly as "606." The story of the origin of this remedy is instructive, especially as it would appear to be a popular delusion that its discovery was merely fortuitous. The reverse was actually the case, though a long series of compounds was examined before one was found which answered the requirements of the scientific theory.

Professor Ehrlich, the distinguished physiologist,

discovered some years ago that the parasitical protozoa connected with sleeping sickness, syphilis, and allied diseases, were selectively stained by the action of dyestuffs containing a particular system of groups. These diseases have been shown to be due to the presence of minute living organisms, termed protozoa, in the blood of the patient. The protozoa particularly connected with such maladies are known as "trypanosomes" or "spirochaetes"; the genus appearing in cases of syphilis being named "spirilla pallida."

Dyestuffs may be described as being made up of two essential parts: the colour-causing part of the molecule; and that system of atomic groupings which renders the colouring matter capable of affixing itself upon tissues. Ehrlich confirmed his experiments by testing the effect of other dyes upon the trypanosomes, ascertaining that no matter what grouping constituted the colour-bearing part of the molecule, these protozoa were always selectively dyed by colouring matters which contained this particular grouping of atoms. From this observation he concluded that it might prove of service to replace the colour-bearing group by a toxic group, in the hope that by the selective attachment of the molecule to the protozoon, this parasite would be poisoned without causing a deleterious effect on any other organism or tissue in the body of the host. The Höchster Farbwerke accordingly undertook the preparation of a series of organic com-

pounds of arsenic which would satisfy the above structural conditions, and as soon as each of these was prepared, its effect on the spirilla and on the living organism was tested by Ehrlich and his assistants. After no less than six hundred and five of these compounds had been examined and had met with little or no success, one was found which appeared to meet all the conditions of the theory. This was "dihydroxydiaminoarsenobenzene." Ehrlich's assistant in the experiments on this substance was a Japanese investigator, Hata, whose name has been associated with that of Ehrlich in the designation first adopted for the remedy. Medical men are still divided as to the degree of its efficacy, but the consensus of opinion points to the entire justification of its claims, and the fact remains that many extremely rapid and apparently permanent cures have been effected by its means. In the last few days, news has been received from Surinam that it has been found to be of equal efficacy in the cure of the allied disease of yaws, caused by a similar spirochaete.

A substance which is not a drug in the strict sense of the word, but which deserves mention in this connection, is saccharine. Synthesised in 1879 by Remsen and Fahlberg, its extremely sweet taste was discovered by accident. It is stated to be five hundred times sweeter than cane sugar, and as it is manufactured from certain products of coal tar, it has been poetically termed "the honey of pre-

historic bees." Its chief application is to the diet of diabetics, since it passes through the body unchanged. So dangerous a rival to sugar is it, that in all countries in which the sugar beet is cultivated a prohibitive protective duty is enforced. Here we see a modern and more subtle equivalent of the action of the Blackburn spinners towards the spinning jenny.

Synthetic chemistry has reproduced not only the sweetness of honey, but the sweet scents of flowers. "The scent industry has received a powerful impetus from synthesis, and yearly turns out in Germany alone goods of the value of more than two million pounds. I shall here show you a few of its numerous products. This bottle contains ionone, an artificial violet-scent discovered in the laboratory of this University by the late Professor F. Tiemann. The contents of this bottle would be sufficient to envelop not only the Ministry of Education, but the entire avenue 'Unter den Linden' in an atmosphere of violet perfume, for the osmophoric value of these subtances is extraordinarily high.

"In contradistinction to the simple ionone, the majority of the natural odours of flowers are due to complex mixtures of different scents. These, nevertheless, have been successfully reproduced. Among the scents here displayed are lily-of-the-valley, mock-orange, lilac, tuberose, and, finally, the greatest achievement, synthetical attar of roses. Although the natural oil from roses contains some twenty different odorous substances the

chemists of the chief scent factories at Leipzig have succeeded, after laborious research, in isolating all the components, synthesising them, or preparing them from less costly oils, and then reuniting them in the correct proportions. It now requires a sensitive nose indeed to distinguish the synthetical attar of roses from the natural product."

The synthesis of scents is directly founded upon the most difficult and complicated processes of chemical research, although odorous constituents of many natural essences, such as the oils of wintergreen or of cloves, have long been recognised as simple organic substances.

Professor Fischer's address concludes with the hopeful words: "These examples show the success which has followed the encroachment of synthetic organic chemistry on nature's realm. What I have already said is sufficient to prove that chemistry offers us the true field of unlimited possibilities. The Kaiser-Wilhelm institutes are henceforth to take part in the expansion of this domain and the appropriation of the treasures hidden therein.

"It is, of course, not to be expected that they will entirely supplant all the older scientific institutions. We of the older institutions do not feel by any means so weak as willingly to allow such an event to occur. On the contrary, we shall exert our best energies to maintain a keen competition with the younger institutes. This will serve to keep both sides fresh and active.

"But there can be no doubt that these godchildren

of the German Emperor will in the healthy air of Grunewald soon develop full strength from the liberal nutrition supplied by their patrons, and grow up into renowned centres of research.

"We may therefore confidently hope that in later years the foundation to-day of the Kaiser-Wilhelm Society will be regarded as an unmixed blessing to scientific research in Germany."

From the above brief survey we have seen how scientific research, whether by direct intention or by happy accident, has benefited and continues to benefit the inhabitants of this globe in countless ways. We have also seen how the nation which possesses sufficient insight to devote an adequate measure of its resources to the furtherance of research has been that which has acquired a control over the scientific industries unparalleled in any other country. It must be patent to all thinking men that the general welfare of England can ultimately be increased only by following the lead thus set by our German neighbours. That this fact is appreciated from a medical aspect is shown by the recent foundation of the Lister Institute of Preventive Medicine; but Medicine requires the support of all its fellow sciences, and would, if left unaided, be unable to progress. It must not be imagined that the call for such institutions as the Kaiser-Wilhelm Society is any whit less urgent in England, or indeed in any other civilised country, than it is in Germany.

CONCLUSION

SINCE the beginning of the present century chemistry has taken an altogether unexpected, and even astounding, development. We have seen how the advent of radium has heralded the return of the long-discarded ideas as to the transformation of the elements, not according to the alchemistical doctrine of the transmutation of the baser metals into gold, but in the sense of the spontaneous conversion of one element into a lower member of the same group in the periodic table. This conversion, termed degradation, consists in the splitting up of heavier atoms into lighter ones.

Just as the chemists of the time of Wöhler stood on the threshold of organic synthesis, which has engendered such marvels as Professor Emil Fischer's synthetical proteid bodies, so do we now stand confronted with elemental transformations. It has been proved beyond cavil that inactive uranium spontaneously yields radio-active uranium-X, and that the active element radium yields its gaseous emanation (niton), which in turn breaks down to the inactive and chemically inert gas helium. But indications of even more striking and suggestive

transformations have been obtained, particularly by Sir William Ramsay.

It is known that niton, by virtue of its radio-active energy, can induce both synthetic and analytic chemical changes. It thus not only causes the partial combination of a mixture of hydrogen and oxygen, but exerts a disruptive effect on water, with formation of these same gases. On treatment of a solution of silver nitrate in like manner, instead of obtaining oxygen and hydrogen, Ramsay found that the hydrogen was almost completely absorbed, metallic silver and oxgyen being produced. He therefore tried the effect of niton upon a solution of copper sulphate, in the expectation that free copper would similarly be precipitated. No such reaction took place. The solution, after prolonged contact with the radio-active emanation, showed, on spectroscopical analysis, the entirely unexpected presence of lithium, a metal closely allied in chemical properties to sodium. As traces of lithium are frequently contained in glass and almost invariably in commercial copper sulphate, this experiment was repeated with great care on several occasions, and controlled by blank tests in which one or the other of the interacting substances was omitted. But the result indicated by the original observation was upheld. The presence of lithium was detected in all those cases, and in those only, in which niton was brought into contact with solutions of copper

salts. From the results of this exhaustive series of experiments little doubt can remain that an actual transmutation had been effected. Moreover, if the principle of such a transformation be conceded, there is no prima facie reason for doubting the conversion of copper into lithium, for an inspection of the periodic table will reveal the position of copper on one of the sub-branches of the group of which lithium is the first metallic member.

Nor was this all. Niton, in common with all radio-active elements, is invested with an enormous store of energy, in the expenditure of which elemental degradations are invariably a concomitant. It has already been stated that niton has been shown to be an element, and that a place for it in the periodic table has been found in the group of inert gases, as is shown by the scheme :

Element	*Atomic weight*
Helium	4·0
Neon	20·2
Argon	39·9
Krypton	82·9
Xenon	130·2
(Unknown)	——
Niton	222·5

It has also been stated that, when allowed to decompose spontaneously, it yields helium. The energy inherent in this element degrades it, therefore, to the lowest member of the group.

Now when water is decomposed by the agency of niton, a portion of the available energy is absorbed in effecting this reaction; and Ramsay has shown conclusively that the inert gas formed by the degradation of the radio-active emanation in the presence of water contains only a minute proportion of helium, and consists almost entirely of neon. It is therefore evident that, on diverting some of the energy, the degradation does not proceed so far.

It is easy to imagine that even more energy would be required to disintegrate copper into lithium than to effect the decomposition of water. And this is borne out by the experiments of Ramsay on the interaction of niton with solutions of copper salts; for among the products of this reaction he detected no trace of either helium or neon, argon being the sole representative of the group of inert gases. Hence what we may assume to be a further diversion of energy from the degradation of the niton has resulted in the arrest of this process at a correspondingly earlier stage.

Indications, moreover, of similar transformations are not wanting. Ramsay enclosed thorium nitrate in evacuated glass vessels, and found that the gases present in the vessel on opening after the lapse of some months consisted largely of carbon dioxide. In blank experiments, in which mercury nitrate was subjected to exactly the same conditions, only the merest trace of carbon dioxide was perceptible. Under the circumstances obtain-

ing in these experiments no explanation of the presence of considerable quantities of carbon dioxide can be advanced unless it is assumed that thorium spontaneously breaks down into carbon.

The results of the experiments above outlined are undoubtedly indicative of the possibility of inducing elemental transmutation, and although this principle has as yet not found favour in the eyes of some of the more sceptical and conservative of scientific authorities, they undoubtedly justify further investigation.

Prophecy, which has been well defined as the most gratuitous form of error, may perhaps be permitted in view of these observations of Ramsay. We are far from being in a position to realise the sordid dreams of the alchemists; the production, by means of a chemical transmutation, of gold from baser elements does not fall into line with our present ideas. For not only would an inconceivable amount of energy be involved in the preparation, by such a transformation, of a quantity of gold equivalent to even the smallest coin of that metal, but no palpable advantage to humanity would be gained were it actually found possible to produce gold cheaply on a large scale. Gold has but slight technical value, its artificially precious quality being due to its comparative rarity, its durability, and to its employment as a token of exchange. But by the study of the phenomena

of degradation we shall not fail to gain an insight into the fundamental nature of elements.

Theories of elemental evolution have already been developed, the earliest of these being the historic theory, promulgated by Prout in 1815, that all elements were polymers—that is to say, complex multiples—of hydrogen. Other notable hypotheses, based on the undoubted relationship of many of the elements, have been put forward since that date, yet no satisfactory solution of the problem has been advanced. Nevertheless we may hope to see the question definitely settled before the lapse of many years.

With regard to the prospects of those tasks which are of more immediate technical importance, we may, in view of the phenomenal development of organic synthesis, safely assert that it will not be long before the great majority of products necessary to the welfare of the race which are at present furnished by nature will have been reproduced by science and provided by scientific industry. The problem of our food supply may, with the advent of fixation of atmospheric nitrogen on a large scale, be stated to be satisfactorily solved. Agricultural research will teach us how best to apply the synthetical chemical manures produced by these processes in a manner which will bring forth the best crops without damage to the soil. It does not at present appear probable that the starchy foodstuffs will be technically reproduced

in the near future, but the recent work of Emil Fischer has so cleared the ground in the matter of synthesis of proteins that synthetical albumens may in the near future find profitable application as a form of nourishment.

In conclusion, a word of warning is necessary. We have seen the multitudinous uses of substances derived from coal-tar. Every year we are burning up the accretions of thousands of centuries of plant life, and so eager are we to derive immediate profit from this store of ages that we blindly and recklessly waste incalculable quantities, not only of valuable chemical material, but of potential work, by the combustion of coal in its natural state. It is but just towards posterity that we should exercise the most rigid economy in the consumption of this by no means inexhaustible commodity; for, bright as are the prospects of chemistry, we can at present perceive no other source from which to obtain the protean series of compounds employed in our chemical manufactures.

The same obvious truth holds good, to a lesser degree, with respect to the other products taken from the earth. If we are to avoid being designated as the "Age of Waste" by future generations, we must devote more study to the principles of recovery.

But these ugly features of our present civilisation will of necessity be remedied when the principles of science at present regarded by so great a

section of humanity as incomprehensible and all but purposeless, are more widely appreciated. It is the duty of all intelligent men to make themselves acquainted with these principles. Having grasped the spirit in which research is undertaken, we shall require no further incentive to do whatever lies in our power to favour the progress of experimental investigation.

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